Nervous System – General

cells, tissues and organs of body are all working for organisms survival

need to *integrate* all body activities for homeostasis

need good communication and control:

Nervous System
Endocrine System
} **Neuroendocrine System**

receptor → integration → effector

General Functions of the Nervous System

1. maintain homeostasis by receiving sensory information and coordinating and transmitting the appropriate responses through muscles and glands

2. working with the endocrine system to integrate rapid reflex responses with slower hormonal responses

3. generate complex neural pathways of all higher brain functions:
   - self awareness
   - thinking, learning
   - speech, communication
   - emotions

Nervous System Structure

cells of the nervous system are highly specialized for receiving stimuli and conducting impulses to various parts of the body

in humans, these nerve cells have become organized into the most complex and least understood of the body's systems

CNS: brain, spinal cord **PNS:** cranial nerves, spinal nerves

Main tissues of the Nervous System

two major cell/tissue types in Nervous System:

1. **neurons** – impulse conduction

2. **neuroglia** (=**glial cells**) – support, protection, insulation, aid in function of neurons

Neurons

neurons – impulse conduction

communicates by:
- electrochemical impulses (=nerve impulses)
- cell-to-cell chemicals (=neurotransmitters)

~100 Billion neurons

most neurons divide only during prenatal development and a few months after birth

after that they increase in size, but not numbers

highly **specialized** to:

respond to stimuli
conduct messages in the form of nerve impulses

generally **don't divide** after birth

→live up to 100 years

very **high metabolic rate:**

require glucose, can't use alternate fuels

require lots of O_2 – only aerobic metabolism
can't survive more than a few minutes without O_2

all neurons have **cell body** and 1 or more **processes**

cell body:

contains: most cytoplasm
nucleus
most organelles
no centrioles (don't divide)
neurofibrils

processes:

two types; **axons** and **dendrites**

Dendrites

shorter; branching

receptor regions

→ each neuron receives info from dozens to 10's of 1000's of other neurons

specialized for information collection
(eg. dendritic spines)

thinly insulated

convey messages *toward* cell body

Axons

each neuron has a single axon

long, slender process

up to 3-4 feet long (eg. motor neuron of toe)

thick insulation

at terminus, axon branches profusely
(up to 10,000 branches)

each branch ends in enlarged bulb
= **synaptic knob** (=axonal terminal)

SHOUT
SHARE
IT

neurons can be classified by:

1. function
2. structure (# of processes)

1. Function

a. sensory neurons

in **nerves** of the PNS
conduct impulses toward the CNS

b. interneurons (association)

in CNS (**brain** and **spinal cord** made of these)
where integration occurs
99% of neurons in body

c. motor neurons (efferent)

in **nerves** of the PNS
conduct impulses away from the CNS

2. Structure

a. unipolar

single short process that splits into two longer processes that together act as an axon

b. bipolar

2 processes; 1 axon, 1 dendrite

c. multipolar

≥3 processes; 1 axon, many dendrites

most common

in very general terms, shape is related to function:

sensory neurons { many unipolar & bipolar
interneurons } mostly multipolar
motor neurons }

<u>Neuroglia Cells (glia)</u>

neuroglia (=**glial cells**) are used for support, protection, insulation, aid in function of neurons

[need specialized cells because of unique sensitivity of neurons to their environment]

10 times more neuroglia cells than neurons (>1 trillion)

some mitosis

several different kinds of neuroglial cells:

1. astrocytes
2. microglia
3. ependymal cells
4. oligodendrocytes

} CNS

5. Schwann cells } PNS

1. Astrocytes

have numerous branches producing a star-like shape

largest and most abundant type

→ comprise >90% of the tissue in some parts of the brain

astrocytes cover the entire brain surface and most of the nonsynaptic regions of the neurons in the gray matter of CNS

also most functionally diverse type

form supportive framework for nervous tissue

direct the formation of tight webs of cells around brain's capillaries

=**blood/brain barrier**

because of "irritability" of nervous tissue and sensitivity to 0_2, glucose etc neurons are isolated into their own "fluid compartment"

this blockage of free exchange between capillaries and tissues is unique for nervous tissue

→ prevents sudden and extreme fluctuations in composition of tissue fluid in CNS

→ protects irreplaceable neurons from damage

capillaries in brain are much less leaky than normal capillaries

→ tight junctions: materials must pass through cells

astrocytes form an additional layer around these capillaries to further restrict exchange

→ astrocytes help regulate flow into CSF

small molecules (O_2, CO_2, alcohol) diffuse rapidly

larger molecules penetrate slowly or not at all

substances easily, rapidly passed by diffusion:

H_2O
O_2
CO_2
lipid soluble solutes:alcohol, caffeine, nicotine, heroin, anesthetics, steroids

some pass by means of membrane carriers:
glucose
amino acids
some ions

substances that cross more slowly
creatinine

urea
most ions (Na^+, K^+, Cl^-)

substances not passed
proteins
antibodies

other functions of astrocytes:

→ secrete growth factors that promote neuron growth and synapse formation

→communicate electrically with neurons and may affect synaptic signalling

→regulate chemical composition of tissue fluid

→ when neurons are damage form hardened masses of scar tissue and fill in the space = **sclerosis**

2. Microglia (CNS)

small cells; act as the brains personal WBC's by removing dead or damaged cells and pathogens

in inflamed or degenerating brain tissue they: enlarge & move about engulfing microbes and cellular debris

3. Ependymal Cells (CNS)

ciliated cells → resemble cuboidal epithelium

line ventricles and spinal canal

help to produce and circulate Cerebrospinal Fluid

4. Oligodendrocytes (oligodendroglia) (CNS)

smaller cells, fewer (up to 15) processes

clustered around nerve cell bodies

each process reaches out to nerve fiber and wraps around it to produce **myelin sheath** (electrical insulation) around neurons in CNS

[myelin=fatty substance]

myelin (in CNS and PNS) can be:

thick = "myelinated fibers", "white matter"

thin = "unmyelinated fibers", "gray matter"

Multiple Sclerosis
autoimmune disease possibly triggered by a virus in genetically susceptible individuals

oligodendrocytes and myelin sheaths of CNS deteriorate and are replaced by hardened scar tissue

occur esp between 20-40 yrs of age
nerve fibers are severed

& myelin sheaths in CNS are gradually destroyed
→ short circuits; loss of impulse conduction

affects mostly young adults

common symptoms:
visual problems
muscle weakness
clumsiness

eventual paralysis

5. Schwann Cells (PNS)

found only in PNS

form a segmental wrapping around nerve fibers
each segment is produced by 1 Schwann cell
gaps between cells = **Nodes of Ranvier**

form **neurilemma** and **myelin sheath** in PNS neurons

myelin sheath similar to that produced in CNS by the oligodendrocytes

outermost coil of Schwann cell with most of cytoplasm & organelles forms **neurilemma**

→ only in PNS neurons
→ plays essential role in regeneration of cut or injured neurons

[CNS neurons don't regenerate]

a study done in 2011 placed nannotubes in a severed spinal cord of rats and found some return of mobility in hind legs

Synapses

neurons are the "wiring" of the nervous system

they take signals from place to place

but the actual "functionality" of the nervous system depends on what is happening where one wire contacts another wire.

eg. any electrical device; computer, CD player, TV, etc

neurons generally are not directly connected to each other but are separated by a small gap

the meeting point between a neuron and any other cells
= **synapse**

synapses are the functional connection between neurons and another cell

neuron → neuron
neuron → muscle fiber [=neuromuscular jct]
neuron → gland [=neuroglandular jct]
neuron → epithelial cells

at synapse the **electrical signal** is converted to a **chemical signal**

=**neurotransmitters**

1. the nerve impulse reaches axon terminal at the synapse and triggers release of a **neurotransmitter**

2. NT diffuses across synapse and binds to **receptor** proteins in cell membrane of target cell

3. triggers some response in target cell

4. the neurotransmitter is then either broken down or reabsorbed by the axon terminal

the whole process takes 0.3 – 5.0 ms

_____

each neuron synapses with 1000 – 10,000 axonal terminals

→ ~1 quadrillion synapses in human brain

100's of different neurotransmitters have so far been discovered

eg. acetylcholine, norepinephrine, serotonin, dopamine, etc

some stimulate the next neuron, some block the next neuron and in some cases more than one synapse must be stimulated to produce an impulse in the next neuron

whether the cell after the synapse is stimulated depends on many factors including:

-how many synapses are active

-which synapses are active

-which neurotransmitters are interacting with each other

-how the specific postsynaptic cell responds to the stimulation

-any modifications caused by surrounding glial cells

synapses make **neural integration** possible

→ each synapse is a "decision making" device that determines whether and how the next cell will respond to the signal from the first

Protection of CNS

both brain and spinal cord are heavily protected:

1. **bone**: skull and vertebral column
2. **adipose cushion** around spinal cord
3. **meninges**: tough flexible covering
4. **liquid cushion**: cerebrospinal fluid

Meninges

composed of 3 layers:

1. dura mater

strong fibrous connective tissue

outer layer in skull is periosteum of cranial bones

2. arachnoid layer

delicate cobwebby layer

subarachnoid space = between arachnoid layer and pia mater

3. pia mater

transparent

adheres to outer surface of brain and cord

contains blood vessels

3 extensions of the meninges form partitions between various parts of the brain:

falx cerebri
largest partition
between cerebral hemispheres

falx cerebelli
separates cerebellar hemispheres
not in sheep brain

tentorium cerebelli
separates cerebrum from cerebellum

meninges continues around spinal cord and extends beyond the end of the spinal cord

→safer site for lumbar puncture to get CSF

Meningitis = inflammation of arachnoid, pia and CSF
usually bacterial or viral; may lead to encephalitis

Encephalitis = inflammation of brain tissue itself

Cerebro Spinal Fluid

as further protection against damage the brain and spinal cord have a cushion of fluid around and within

→ brain actually "floats" in CSF (~140 ml of CSF)

CSF provides buoyancy and protection to delicate brain tissues also produces chemical stability

CSF mainly in:

a. brain **ventricles** and **ducts**

b. **central canal** of spinal cord

c. in **subarachnoid space** of the **meninges**

→space between arachnoid layer and pia mater

ventricles are fluid filled cavities inside brain:

1st & 2nd inside cerebral hemispheres = lateral ventricles

3rd small slit inside diencephalon (mainly thalamus)

4th diamond shaped expansion of central spinal canal in brainstem

capillary beds called **choroid plexuses** are found in each of the 4 ventricles of the brain where they secrete **cerebrospinal fluid**

the capillaries are surrounded by **astrocytes** forming a **blood brain barrier** that controlls what kinds of chemicals enter the CSF

produces ~500ml of CSF/day

→ only 100-160ml at a time in circulation

Circulation of CSF

fluid moves from lateral ventricles through **duct** to 3rd ventricle

another **duct** moves fluid to 4th ventricle

fluid moves to **central canal** of spinal cord

fluid moves out to **subarachnoid space** around cord and brain

reabsorbed from subarachnoid space into **arachnoid granulations** of the meninges

if circulation is blocked by tumor or other means during fetal development may cause **hydrocephalus**

→ fluid is still produced but can't circulate and be reabsorbed

Central Nervous System
Brain & Spinal Cord

Brain

one of the largest organs in body:

men: 1,600 g (3.5 lbs)
women: 1,450g (3.2 lbs)

[brain size is proportional to body size not intelligence → Neanderthals had larger brains than us!!]

early thoughts on function of brain:
ancient Greeks weren't particularly impressed with the brain
where snot was generated
cooling device for blood

the brain is one of most metabolically active organs in body

comprises only 2% of total body weight it yet

→ gets 15% of blood

→consumes 20% of our oxygen need at rest (more when mentally active)

blood flow and O_2 increase to active brain areas

1-2 min interruption of blood flow may impair brain cells

>4 min w/o oxygen → permanent damage

besides O_2 must get continuous supply of glucose

very little in reserve

decrease in glucose:
dizziness
convulsions
unconsciousness

one of the brain's most impressive features is it's ability to store information:

compared to computer memory one estimate of the brain's storage capacity based in number of neurons and number of synapses is 1 Million Gigabytes

→ the equivalent of ~3 million hours of DVD images

Some General Terminology for CNS:

one of the most obvious feature of the surface of the brain are the folds:

gyri = raised areas
sulci = fissures between the gyri

-found in the **cerebrum** and the **cerebellum**

gray matter = thin myelin; mostly cell bodies dendrites & synapses

-outer layer of brain = **cortex**

-inner layer of spinal cord

-**nuclei**: small areas of gray matter deeper inside the brain

white matter = thick insulation; mostly axons

nerve tracts = bundles of axons that interconnect various parts of the brain

-inner layers of brain:

-outer layer of spinal cord

The Brain is Subdivided Into:

1. **Cerebral Hemispheres**

"human" part: thought, creativity, communication

2. **Diencephalon**

moods, memory, manages internal environment

3. **Cerebellum**

coordinating movement and balance

4. **Brain Stem**

basic bodily functions = vegetative functions

Brain Stem

1. **Medulla**

lowest portion of brainstem

continuous with the spinal cord

all ascending and descending **tracts** from spinal cord and brain = **white matter**

most tracts **cross over** as they pass through the medulla

also contains **nuclei** (gray matter) that are important **reflex centers** that help to control several vital functions

cardiac reflex center
rate and force of heartbeat

vasomotor control center
controls diameter of blood vessels
controls the distribution of blood to specific organs
controls blood pressure

respiratory center
regulates the rate and depth of breathing

polio especially affects this center in medulla
→ resp failure (iron lungs)

also contains many nonvital reflex centers (nuclei):
speech
swallowing
vomiting
coughing
sneezing
hiccuping

2. **Pons**

just above medulla

bridge connecting spinal cord with brain and parts of brain with each other

contains 2 additional respiratory centers (nuclei) that help to regulate breathing

also contains nuclei that affect sleep and bladder control

3. **Midbrain**

in the form of 4 lobes above and behind pons
(= **Corpora Quadrigemina)**

control centers(nuclei) for some visual & auditory reflexes:

a. **pupillary reflex**

b. reflex centers for **coordinating eye movement** with head and neck movement in response to visual stimuli

c. control center for **auditory reflexes:**

eg. reflex centers for movements of head and trunk in response to auditory stimuli to locate sound

eg. startle response to loud noises

also contains a nucleus of gray matter called the **substantia nigra**

→ suppresses unwanted muscle contractions

Parkinsons Disease
progressive loss of motor function
begins in 50's or 60's
can be hereditary
due to degeneration of dopamine releasing neurons in **substantia nigra** (inhibitory neurons)
leads to hyperactivity of **basal nuclei** and involuntary muscle contractions
results in shaking hands, facial muscles become rigid, range of motion decreases
develops smaller steps, slow shuffling gait with forward bent posture and a tendency to fall forward
speech becomes slurred, handwriting illegible

4. **Reticular Formation (~Reticular Activation System)**

diffuse system of interconnecting fibers extending through several areas of brain including brain stem

-comprises a large portion of entire brainstem
-extends into spinal cord and diencephalon
-interlacing of gray and white matter

Functions of RAS - both sensory and motor

1. Sleep and consciousness

maintains consciousness and awakens from sleep → alarm clock

barbiturates depress RAS, decrease alertness & produce sleep

amphetamines stimulate RAS producing wakefulness

general anesthetics may produce unconsciousness by depressing RAS

falling asleep may be caused by specific neurotransmitters that inhibit RAS

2. **helps control muscle tone, balance and posture** during body movements

3. **filters flood of sensory input** (=habituation)

highlights unusual signals; disregards rest (99%)

LSD interferes → get flood of sensory stimuli

Diencephalon

1. Epithalamus

includes roof of 3rd ventricle

mainly pineal gland – an endocrine gland that controls cyclic activities

2. Thalamus:

the largest part of the diencephalon

encloses a fluid filled cavity = **3rd ventricle**

mainly a sensory relay center

→ *"Rome of the Nervous System"*
or
"gateway to cerebral cortex"

→ main **relay station for sensory impulses** that reach cerebral cortex from spinal cord, brain stem and cerebellum

eg. taste, touch, heat, cold, pain, etc

3. Hypothalamus

forms the floor of the 3rd ventricle

includes the **pituitary gland** (the "master gland" of the endocrine system)

part of the brain most involved in regulating internal environment

a. link between "mind" and "body"

controls and integrates many autonomic (automatic, unconscious) activities

means by which emotions express themselves by altering body functions

→ ?role in psychosomatic illnesses

b. regulates body temperature

has receptors that monitor blood temperature

c. regulates food and water intake

has receptors that monitor osmotic pressure → thirst center

4. Limbic System

diencephalon is a main part of a diffuse group of structures called the **Limbic System**

= the emotional brain

limbic system perception & output is geared mainly toward the **experience & expression of emotions**

eg. pain, anger, fear, pleasure

continuous back & forth communication between limbic system and frontal lobes of cerebrum

→ much of the richness of your emotional life depends on these interactions

all sensory impulses are shunted through the limbic system

produces a crude appreciation of some sensations;

eg. pleasure, fear, anger, pain

but can't distinguish their location or intensity

eg. contains **pleasure center**

-rats pressing bar for stimulation of pleasure center
-ignore sleep, food, water, sexual partners
-continue until exhausted (50-100x's/min)
-willing to cross electrified grid to seek reward
[420 μamps vs 60-180 μamps for food]

in humans stimulates erotic feelings

opioids and endorphins are concentrated in limbic pathways

→is site of action of many addictive drugs

a few who lack the amygdala (part of the limbic system) have no sense of fear

also involved in the formation of memories

Cerebellum

2nd largest part of brain

just below and posterior to cerebrum

only other part of brain that is highly folded

consists of 2 hemispheres

grey matter outside

white matter inside

= **arbor vitae** (tree of life)

Functions of Cerebellum:

helps to coordinate voluntary muscles:

but does not send impulses directly to muscles

1. acts with cerebrum to **coordinate different groups of muscles**

   smooths and coordinates complex sequences of muscular activity needed for body movements

2. controls skeletal muscles to **maintain balance**

   receives input from proprioceptors in muscles, tendons and joints and equilibrium receptors and eyes

   → compares intended movement with actual movement

3. **learning and storing motor skills**

   eg. playing musical instrument, riding a bike, typing, etc

4. recent research indicates that the cerebellum also has roles in awareness, emotion and judging the passage of time

diseases of cerebellum produce **Ataxia**

eg. tremors
speech problems
difficulty with equilibrium

NOT paralysis

<u>Cerebrum</u>

largest portion of brain (~60% of brain mass)

divided into two **cerebral hemispheres**

two hemispheres joined by nerve tracts = **corpus callosum**

heavily convoluted surface: **gyri** and **sulci**

folding allows greater area of cortex in smaller space (area = 2,500 cm^2 = area of 4.5 textbook pages or 1 keg of beer)

each hemisphere:

a. outer **gray matter** = cerebral **cortex** (2-4mm)

this is where the synapses, the connections between neurons occur

the cortex is the "functional part" of the cerebrum

b. inner **white matter** = **tracts**

→ bundles of myelinated axons
the white matter connects the various functional parts of the cerebrum for integration (the wiring)

c. **nuclei** = islands of gray matter in the interior of brain

→ cell bodies and sometimes dendrites

eg. basal nuclei (=basal ganglia)
clusters of gray matter around thalamus (5)
help direct skeletal muscle movements

Function of Cerebral Cortex:

1. cerebrum is responsible for our most "human" traits

   conscious mind
   abstract thought
   memory
   awareness

   → most of these will be discussed later under integration

2. the cerebrum also contains some more basic functional areas:

   a. motor areas
   that control voluntary motor functions

b. sensory areas
provide conscious awareness of sensations

c. association areas
integrate wide variety of information from several different areas of brain

each hemisphere is mainly concerned with sensory and motor functions of the opposite side of the body

eg. left hemisphere controls right hand

3. in addition to the general functions of the cerebrum, each hemisphere has its own specific jobs to do

   =Lateralization of Hemispheres

   a division of labor

   → each hemisphere takes on complementary functions

Left Hemisphere:

→ repository of language: processes many aspects of language: syntax, semantics, etc

"does all the talking"

→ more involved in analytical skills

eg, math, logic

Right Hemisphere:

→ nonverbal communication: interprets more subtle aspects of language - metaphor, allegory, ambiguity

→ also concerned with emotions, intuition

eg. reading facial expressions

eg. recognizing faces

→ mainly concerned with **visuospatial tasks**

the "artistic" duties of the brain

Hemispheric Dominance:

in ~90% of population → **left hemisphere are dominant**
more verbal, analytical
are right handed

in 7% of population → **right hemisphere are dominant**
visuospatial tasks
are left handed
more likely to be males

in 3% of population → **functions are shared equally**
=bilateral (no right or left dominance)
often ambidextrous
sometimes leads to confusion and dyslexia

4. the cerebrum also has larger grooves (= **fissures**) that divide each hemisphere into 4 main **lobes** or regions

each lobe is named after the bone it lies under:

Lobes of the cerebrum
1. **frontal**
2. **parietal**
3. **occipital**
4. **temporal**

within each lobe is a further specialization of function:

1. Frontal (& prefrontal)

a. most anterior part of the frontal lobe (just behind forehead (=prefrontal)
elaboration of thought
intelligence
motivation
personality
abstract ideas
judgement
planning
"civilizing behaviors"

damage:
wide mood swings
loss of attentiveness
become oblivious to social constraints
careless about personal appearances

prefrontal lobotomy
reduced anxiety

but lost initiative
had mood swings

b. **Olfactory Cortex**

small area just above orbits
perception of odors, smells

c. at the back of the frontal lobe is the **Motor Cortex**

directs conscious control of muscle contractions

coordinates groups of muscles; not individual muscles

if damaged may cause paralysis

or person has trouble directing learned muscular coordination eg typing, tying shoes

can visualize specific body zones
→ homunculus

2. Parietal Lobe

a. sensory processing areas **Sensory Cortex**

at the front of the parietal lobe

receives information from muscle, tendon and joint sensations, and touch

when stimulated patient reports "feeling" in

some part of body

motor and sensory cortex, like other areas are malleable

eg. learning Braille
the area representing touch in the finger used in learning braille expands into areas previously devoted to neighboring fingers

relates sensations to past experiences

b. **Gustatory Cortex**

conscious awareness of taste stimuli

3. Occipital Lobe

the entire lobe is devoted to visual processing

image is 1st mapped onto visual cortex based on nerve impulses received from the eyes

image is analyzed in terms of its elementary features

orientation
color
texture
depth
presence of movement

other areas interpret and associate image with past visual experiences

→ recognize people, flowers, etc

4. Temporal Lobe

a. hearing is processed by the **Auditory Cortex**

interprets sounds: pitch, rhythm, loudness

b. area for balance and equilibrium

awareness of position and orientation, etc

Spinal Cord

located in the spinal canal of the vertebral column

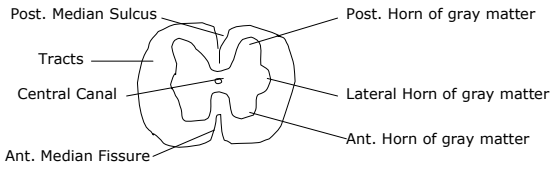
17 – 18 inches long

extends from **foramen magnum** to lower border of 1st lumbar vertebrae

subdivided into **cervical**, **thoracic**, **lumbar**, **sacral** regions

spinal cord terminates in a bundle of nerves = **cauda equina** (horses tail)

Cross Section of Spinal Cord:



white matter: myelinated, divided into columns and tracts; "highways"

numerous tracts can be identified in the spinal cord

spinal cord tracts serve as 2-way conduction paths between peripheral nerves and brain

each tract is composed of bundles of axons

ascending tracts & descending tracts

each tract is a structural and functional unit:

eg. spinothalamic tract
all axons originate from cell bodies in spinal cord and terminate in thalamus of brain
all are sensory (ascending)

gray matter: unmyelinated, cell bodies & dendrites, synapses

Peripheral Nervous System

Nervous system consists of

CNS = brain and spinal cord

all interneurons

~90% of all neurons in body are in CNS

PNS = **nerves**, **ganglia** & **nerve plexuses**

sensory and motor neurons

~10% of all neurons in body are in PNS

PNS is our link to the outside world

without it CNS us useless

sensory deprivation → hallucinations

some terminology:

	CNS	PNS
bundles of axons	tract	nerve
cell bodies, dendrites, synapses	nuclei	ganglia

Nerves

each nerve is an **organ** composed mainly of nervous tissue (neurons and neuroglia) and fibrous connective tissue with rich supply of blood vessels

arranged in pattern similar to that of muscle organs:

endoneurium →around each individual neuron

perineurium →around bundles of neurons (=fascicles)

epineurium →around entire nerve

2 kinds of neurons can be found in nerves:

sensory (afferent) neurons
~2-3M; 6-8x's more sensory than motor fibers

motor (efferent) neurons
~350,000 efferent fibers

Nerves can be classified according to the kinds of neurons they contain:

a. sensory nerves – contain mainly/only sensory neurons

b. motor nerves – contain mainly /only different kinds of motor neurons (somatic or autonomic)

c. mixed nerves – contain a combination of both

Ganglia

= groups of cell bodies and sometimes dendrites and synapses associated with nerves of PNS

examples of PNS ganglia:

Nerve Plexuses

weblike interconnected fibers from several different nerves

Cranial Nerves

PNS consists of 43 pairs of nerves branching from the brain & spinal cord:

12 pairs of cranial nerves
31 pairs of spinal nerves

most cranial nerves originate from the brainstem which contains most of the automatic (vegetative) functions of the body

some cranial nerves are **sensory** nerves, some are **motor** and some are **mixed** nerves

a. **sensory** cranial nerves

I. **Olfactory** [sense of smell]
II. **Optic** [sense of sight]
VIII. **Vestibulocochlear** [senses of hearing and balance]
has a few motor fibers
-injury causes deafness

b. motor cranial nerves

III. **Oculomotor**
IV. **Trochlear**
VI. **Abducens**
} [eye movements]
-injury to VI causes eye to turn inward

c. **mixed** cranial nerves

–contain a large number of both sensory and motor neurons

IX. **Glossopharyngeal** [sense of taste, swallowing]

XII. **Hypoglossal** [tongue]
V. **Trigeminal** [cutaneous senses of head and face, chewing muscles]
VII. **Facial** [sense of taste, facial expression]
X. **Vagus** [sensory and motor to larynx, heart, lungs, digestive system]
XI. **Accessory** [shoulder and head]

severe head injury often damages one or more cranial nerves

Spinal Nerves

31 pairs

all are mixed nerves

all but 1st pass through **intervertebral foramina**

they are named and numbered according to the level of the vertebral column from which they arise:
8 cervical
12 thoracic
5 lumbar
5 sacral
1 coccygeal

each spinal nerve is attached to spinal cord by two roots:

dorsal (posterior) **root** → sensory neurons and a **ganglion**

ventral (anterior) **root** → motor neurons

the two roots joint to form a mixed, spinal nerve

Dermatomes

sensory neurons of each spinal nerve innervate the skin and skeletal muscles in the roughly same order in which they emerge from the spinal cord

→ **segmental arrangement** of spinal nerves

this is clinically useful since physicians can determine the site of spinal damage by simple pinprick exam

Spinal Nerve Plexuses

after the spinal nerves exit the intervertebral foramina they branch and interconnect to form **plexuses**

from these plexuses new nerves emerge that contain a mixture of fibers from various spinal nerves

Cervical Plexus

formed from C1 – C4,5

supplies sensory and motor neurons to head, neck and upper shoulders

emerging nerves include:

phrenic nerve (C3-C5) → diaphragm

Brachial Plexus

formed from fibers in C5 to C8, & T1

innervates shoulders and upper limbs

emerging nerves include:

axillary (C5,C6) → to deltoid
radial (C5-C8,T1) → triceps and forearm extensors
median (C5-C8,T1) → flexor muscles of forearm and hand
ulnar (C8,T1) → wrist and hand muscles

this plexus is sometimes stretched or torn at birth leading to paralysis and numbness of baby's arm if untreated may produce "withered arm"

prolonged use of crutch may injure this plexus = **crutch palsy**

[most thoracic spinal nerves (2-12) do not form a plexus]

Lumbar Plexus

formed from fibers in L1 to L4

innervates abdominal wall, genitals, parts of leg

emerging nerves include:

femoral nerve (L2-L4) → thigh and leg muscles

Sacral Plexus

formed from fibers in L4 & 5, S1 to S4

supplies nerves to buttocks, perineum, leg

emerging nerves include:

sciatic nerve (L4,L5, S1-S3) → leg muscles; largest nerve in body

sciatica

sharp pain that travels from gluteal region along posterior side of leg to ankle
90% of cases result from herniated discs or osteoarthritis of lower spine
can also be caused by infections, pelvic fractures, spinal stenosis
also sitting on wallet, or edge of hard chair too long
about half the time the pain resolves spontaneously in about a month

Autonomic Nervous System

the PNS is made up of sensory and motor neurons

there are two different kinds of **motor neurons**:

somatic motor neurons - innervate skeletal (voluntary) muscles

autonomic motor neurons – innervate smooth and cardiac (involuntary) muscles and glands

Somatic	Autonomic
voluntary effectors: striated muscles	**involuntary effectors: smooth & cardiac muscles, glands**
somatic reflexes	**visceral reflexes**
single motor neuron from spinal cord to target organ	**usually 2 neurons with synapse (ganglion) between from spinal cord to target organ** presynaptic vs postsynaptic
NT always stimulatory	**NT stimulatory or inhibitory**
ACh released at synapse	**ACh or NE released at synapses**
No firing at rest	**Baseline firing – speeds up when stimulated**
effector at rest is flaccid	**effector at rest has intrinsic tone**

finally, there are two major kinds of autonomic motor neurons:

sympathetic (sympathetic branch)

parasympathetic (parasympathetic branch)

Structure of the Sympathetic Branch

formed mainly by neurons from **thoracic spinal nerves**

sympathetic neurons branch from spinal nerves as they exit intervertebral foramina and form interconnected ganglia (= **chain ganglia**) on each side of vertebral column

sympathetic fibers are all interconnected

synapses of sympathetic fibers rely mainly on 2 neurotransmitters:

ACh is secreted from preganglionic fibers (inside chain ganglia)

NE is secreted from most post ganglionic fibers (at organ innervated)

Structure of the Parasympathetic Branch

formed by neurons from a few **cranial** nerves mainly the **vagus nerve**

and some sacral **spinal** nerves

ganglia are usually near organs they innervate

no chain ganglia, not all interconnected

all synapses of parasympathetic fibers secrete **ACh** as the neurotransmitter

Function of the Sympathetic Branch

acts as an **emergency system**
emergency or stress that threatens homeostasis
"fight or flight"

adapts body for intense physical activities:
increases alertness, blood pressure, air flow, blood sugar concentrations, blood flow to heart and skeletal muscles

acts as a unit = **mass activation**

more diffuse, body-wide response involving hormones

→effects are longer lasting

Studies show that animals cannot live in nature without a functioning sympathetic NS

Function of the Parasympathetic Branch

most active in non-stressful, non-emergency situations

"resting and digesting"

tends to have a calming effect on body:
reduced energy expenditure and normal body maintenance

organs are individually activated
no mass activation

ACh is quickly produced and quickly destroyed
→ short lived, localized effects

promotes normal daily activities:
GI tract works to process food
> glandular secretions
> peristalsis

blood pressure, heart rate, respiratory rates maintained at low levels

Interactions between two branches of ANS

the body doesn't *alternate* between only sympathetic or parasympathetic activity

most visceral organs receive dual innervation of both branches of ANS

normally, both systems are active; it is the ratio between the firing rate of sympathetic and parasympathetic fibers that determines the function of most organs

eg. heart
> sym stimulation → faster
> parasym stimulation → slower

eg. digestive tract
> sym stimulaton → inhibits
> parasym stimulation → promotes

eg. respiratory system
> sym stimulation → dilation (inhibition) of air passages
> parasym stimulation → constriction

Neurophysiology

Membrane Potential

there are small differences in electrical charge between inside and outside of cell membranes

more – ions on inside; more + ions on the outside of cell membranes

+ + + + + + + + + + +
- - - - - - - - - - -
- - - - - - - - - - -
+ + + + + + + + + + +

this differences in charge = **membrane potential**

potential difference is stored energy (like a battery)

it is measured as voltage (like batteries)

resting cells (all cells in body) have a membrane potential that averages ~ **0.1 volts/cell**

only nerve and muscle cells can use this stored energy to do something

= **resting potential**

if the nerve cell (or muscle cell) is stimulated in some way it causes + ions to rush into the cell

briefly reverses the resting potential

→ more + inside; more – outside

this reversal of charge is called an **action potential**

↓

- + + + + + + + + + +
+ - - - - - - - - - -
+ - - - - - - - - - -
- + + + + + + + + + +

once an action potential is produced it causes the areal of the membrane immediately adjacent to the action potential to do the same thing

this in turn triggers the next area and so on

→ the action potential moves down the neuron

as new area is depolarizing, original area is repolarizing and returning to resting potential

→ at any one time action potential occurs at only one small area of axon

+ + + + + - + + + + +
- - - - - + - - - - - -
- - - - - + - - - - - -
+ + + + + - + + + + +

=**nerve impulse**: a self propagating wave of action potentials moving down an axon

Characteristics of a Nerve Impulse

1. **nerve impulse** is all-or-none (like AP)
   above threshold – fires
   below threshold – doesn't fire
2. does not decrease in strength as AP moves along axon
3. a **stronger stimulus** increases **frequency** of nerve impulse

   not the size of the nerve impulse
4. just as with motor end plates, a number of physical and chemical substances can affect the generation of a nerve impulse

   a. Calcium ions

   low Ca^{++} → repeated transmission of AP
   → muscle spasms

   eg. decrease of Ca^{++} in blood of pregnant women sometimes produces spasms

   eg. spasms can also be produced by diarrhea, vit D deficiency, etc.

   b. Caffeine

   lowers threashold of nerve impulse

   →causes neuron to fire more easily

   c. Alcohol, sedatives, anesthetics

all block nerve impulses by reducing membrane permeability to ions, mainly Na^+

→ No Na^+ → no action potential

d. Cold Temperature

interrupts blood flow

block delivery of oxygen and glucose to neurons

impairs their ability to conduct impulses
cold → numb

e. Continuous Pressure
interrupts blood flow as well

eg. foot goes to sleep
→ when relieved impulses begin
→ create prickly feeling

Reflexes

reflexes are the most basic functions of the nervous system

reflex = a rapid, automatic, predictable motor response to a stimulus

unlearned
unplanned
involuntary

→ "hard wired" into our neural anatomy

many of the body's control systems occur at this most basic functional level of neural activity
→ **reflexes**

the simplest reflexes are the result of a circuit called the **reflex arc**

= simplest **functional unit** in nervous system

(just as the motor unit is the simplest functional part of the muscular system)

components of a reflex arc:
receptor
sensory neuron
integration center (CNS)
motor neuron
effector

very few *complete* neural circuits are **simple** reflexes

most are more complex reflexes with numerous interconnections to many parts of the brain

Higher Brain Functions

what we consider some of our most human traits result from much more elaborate interconnections of neurons and synapses

involve complex processing

some examples of higher cerebral integration and processing:

1. <u>Language and Speech</u>

language is closely associated with distinctly human brain functions

seems to be an innate process

→world's languages are all governed by the same universal grammar

→ all infants are born with the ability to learn all human languages

however this ability diminishes with age

integrated with memory and consciousness

it can't be all under conscious control since it happens so quickly

also, cant be all reflex

Language involves up to 6 or 7 areas in cerebral cortex:

1. **Broca's speech area** (frontal lobe)
   motor aspects of speech and language
   active when speaking
   or when moving tongue and hands
   muscular coordination for speech
   damage: aphasia
   slow and poorly articulated speech
   loose ability to speak fluently and grammatically and to express ideas in writing
   comprehension not affected

2. **Wernicke's Area** (temporal lobe)
   comprehension of written and spoken word
   active in children while reading
   and in adults reading unfamiliar words
   speech integration
   impulses from visual and auditory assoc
   connects to Broca's area
   damage: aphasia
   rapid, fluid speech
   no information content– "word salad"
   no comprehension of spoken or written language

   in right handed people these centers are found in left hemisphere

   most left handed people have them in right hemisphere

3. neurons in Left frontal and midfrontal cortex
   responsible for semantics
   word associations
   symbolic processing
   [originally thought this occurred in Werneke's area]

4. Left Frontal Cortex
   essential for enunciating verbs

5. Left temporal cortex
   "whips out" nouns

6. Occipital Lobe
   color concepts and associations

Disorders of Speech:

Stuttering
affect 1% of adults
has been known from earliest history
2002 research – found fibers in a speech motor control area on left side of brain were 30% less tightly packed than in nonstutterers
another study found that the Wernicks and Brocas areas near these fibers are also different between stutterers and nonstutterers

Dyslexia
individuals have difficulty associating letters with corresponding sounds and distinguishing letters that are similar in form

may also read words backwards

est 10-15% of population in US is affected

more common in boys and left handers
→ might involve deficit in development of dominance by left hemisphere

also Wernicke's area is reduced in size in dyslexics

2. <u>Consciousness</u>

What exactly is consciousness?

little is actually known but some generalizations:

1. involves simultaneous activity of large areas of cerebral cortex
   → localized damage of specific region does not destroy consciousness but does alter it

2. is superimposed onto other types of neural activity

3. is totally interconnected

there are many levels of consciousness; awake & aware, sleep, coma, drug "trip", locked-in state, etc

<u>Awareness</u>

one of the simplest forms of consciousness is **awareness (=perception)**:
of surroundings
of sensations
of relationships to those stimuli

not the same thing as **sensation**
→ **sensation** = sensory stimuli
→ **perception** = conscious interpretation of

stimuli

consciousness is often defined as "self" awareness

what is **self**? or self identity
→ requires interactions of numerous specific brain areas

<u>Role of Vision in Consciousness</u>

one of most important senses that gives us information about our surroundings and interactions with it is **vision**

→ ~1/2 of all sensory neurons in body are in optic nerve

visual stimuli that reach brain are first mapped into visual cortex
visual imprint of retinal image:

from there it goes to ~30 areas in cortex for higher level processing

information from primary visual cortex is then relayed through 2 pathways:

→ **How Pathway** to parietal lobe
to discern spatial layout of outside world

allows you to reach out for objects, know where you are

→ **What Pathway** to temporal lobe
to recognize and name individual objects

and respond to them appropriately with emotion

(?the man who mistook his wife for a hat?)

eg Neglect patients
esp if Rt parietal lobe is damaged

The right hemisphere has broad "sphere of interest" encompasses both left and right visual fields

If right is damaged
→ temporary **neglect** of left side of body
doesn't pay attention to left side of space or anything in it

eg. draw 1/2 of a picture
(left doesn't exist)
eg. eat from only rt side of plate
-one patient "knew something wasn't right"
-rolled wheelchair in huge circle (clockwise) till she could "see" the left side of the plate in her right field of view
-never occurred to her that she could just turn left
-left didn't exist

→also show "mirror confusion"
try to reach through mirror for objects

→ also may have difficulty reading maps or finding their way around the house

is not blindness but indifference

receives sensation, lacks correct perception of what they indicate

visual awareness (perception) is not just the image imprinted on retina

it's a **neural image** formed in cortex

that neural image is not a completely accurate representation of what is going on in the world

brain can "fill in" (eg. blindspot) by extrapolation
- eg. blind spot is filled in
- eg. Necker cube
- eg. faces/vase

some have larger areas of "blindness" due to damage and fill in with hallucinations:
- → no reaffirming information to "squash" hallucinations
- → sometimes patient "knows" they are hallucinating – but can't get rid of them
  - eg. monkeys in lab
  - eg. cartoon characters

Synesthesia

all of our senses contribute to consciousness

(not just vision)

some experience **"synesthesia"**

→ hallucinatory welding of senses:
2 or more sensations are comingled

1 person in 2000 is a synesthete;
but may be even more common 1 in 300

more common in women: 6 women to 1 male

seems to run in families: genetic component

sensory impulses are not sent to appropriate sensory areas of cortex

- eg. a musical note may taste like pickles
- eg. a guitar chord may be felt as a brushing sensation on ankle
- eg. the taste of chicken may feel "round"
- eg. a boyfriends kiss was seen as "orange sherbert foam"
- eg. see brilliant blue after eating salty pretzel
- eg. specific letters or number → associated with specific colors
- eg. feel pain in colors

these perceptions are consistent over time for one person

but not necessarily the same for other synesthetes

Is there a consciousness "center" in the brain?

does consciousness arise from specialized brain circuits?

→ brain lesions that produce the most profound disturbances in consciousness are due to "temporal lobe seizures"

temporal lobe is associated with auditory hallucinations, out of body experiences, "religious" experiences

→ epileptic seizures sometimes produce profound experiences

→ feelings of absolute omnipotence & omniscience

→ insights into "cosmic truths"

3. Intelligence

what is anatomical/physiological basis for intelligence?
- → brain mass?
- → # neurons in brain?, in cerebrum?
- → # synapses?

where is it centered?
→is our intelligence part of our cortex?

What we know:

a. intelligence may have more to do with when and how the brain grows than with its overall size

→the brain regresses as it matures

eg. the cerebral cortex thickens in childhood, peaks and

then thins again in adolescence

→2x's # synapses in certain areas of child's brain vs adolescent brain

b. angular gyri in cerebral hemispheres is important

eg. we know damage to angular gyrus in left hemisphere can leave "intelligent" people unable to do simple subtraction (eg. 100-7)

eg. we know damage to angular gyrus in right hemisphere leads to disruption of artistic skills

c. specific circuits are used for specific functions

Savants are mentally retarded yet some can:
- → replay any music when heard once
- → state exact time of day with no clock in sight
- → exact counts of numerous objects
  eg "rainman"
- → can tell you in span of 40,000 years, the day of the week any date you choose fell on

*Jeremy can stand at the side of the railroad tracks and give you the cumulative total of the serial numbers on the boxcars

*George can tell you all the years in which your birthday fell on a Thursday

* George can also tell you within a span of 40,000 years backward or foreward, the day of the week on which any date you choose fell or will fall

*Leslie, upon hearing Tchaikovskys Piano Concerto No 1 on the piano for the first time can play it back flawlessly and without hesitation

*Ellen constructs complicated chords to accompany music of any type she hears on radio or TV. She can sing back the entire soundtrack of the musical Evita after one hearing while transposing orchestra and chorus to the piano

*Kenneth can give the population of every city and town in the US with a population over 5,000; the names, number of rooms and locations of 2,000 leading hotels in the US; the distance from each city and town to

the largest city in its state; and the dates and essential facts of over 2,000 inventions

*Jedediah can answer the question: "in a body whose three sides are 23,145,789 yards, 5,642,732 yards and 54, 965 yds, how many cubicle $1/8^{th}$'s of an inch exist" after 5 hours of computation he has the correct 28 digit figure and asks "do you want it backwards or forewards"

*David can be given the number of the bus and time of day, and tell you on what corner you are standing in milwaukee

most savants are not truly "creative"
rote, not interpretive

some now believe that we all have these skills but they only show up when higher order cognition is shut down

d. there is lots of redundancy and plasticity in the brain in terms of intelligence

John Lorber asks:
"*Is your brain really necessary?*"

most of brains higher functions are mediated by cortex
→we view the cerebrum as what makes us human

he studies **hydrocephalic** patients
→ extremely large cavities in brain, brain mass, including cerebral cortex is greatly reduced

many hydrocephalics suffer intellectual and physical retardation

but of ~60 whose brain scans showed water

cavities filled 95% of skull
→ ~ half had IQ's > 100 (normal IQ=90-110)

eg. Hydrocephalic boy = honor student
had <20% of normal cerebral cortex
(his 1 mm (1/32"); normal = 4.5 cm (1.75"))

normal IQ = 90-110; his = 126

Aging Central Nervous System

reaches peak development ~30

by age 75 average brain weighs slightly half its 30 yr weight

gyri are narrower
sulci are wider
cortex is thinner
more space between brain and meninges

neurons show signs of slower metabolism, accumulate neurofibrillary tangles and lipofuscin pigment

less efficient signal conduction and transmission

myelin sheath degenerates

fewer synapses

less NT produced, fewer receptor proteins

language skills and long term memory hold up better than motor coordination, intellectual function and short term memory

Disorders of the
Nervous System

Multiple Sclerosis
autoimmune disease possibly triggered by a virus in genetically susceptible individuals
oligodendrocytes and myelin sheaths of CNS deteriorate and are replaced by hardened scar tissue
occur esp between 20-40 yrs of age
nerve fibers are severed
& myelin sheaths in CNS are gradually destroyed
→ short circuits; loss of impulse conduction

affects mostly young adults
common symptoms:
visual problems
muscle weakness
clumsiness
eventual paralysis

Tay-Sachs Disease
hereditary disorder seen mainly in infants of Eastern European Jewish ancestory
abnormal accumulation of a certain glycolipid (GM_2)in myelin sheath
as it accumulates it disrupts conduction of signals
results in blindness, loss of coordination ,dementia
symptoms appear before 1 yr of age, death by 3 or 4

migraine headaches:
often debilitating and excruciating headaches
10-12% of US →28M in US suffer;
~70% are women
92 M workdays lost/yr; $11 B/yr (AAS 97)
2 kinds:
Classic (with aura)

some or all of symptoms:
- seeing zigzagging lines
- tingling or numbness in face, arm, leg
- seeing blind spots and tunnel vision

Common (without aura)
- pain on one or both sides of head

nausea
- sometimes vomiting
- sensitivity to light, smell or noise
- throbbing, intense pain

may be due to:

a. fluctuations in levels of serotonin
   - imitrex increases serotonin levels to stop headache

b. excessive levels of dopamine

c. may be a genetic component

Tourette's Syndrome

recurrent involuntary muscle contractions = tics
- eg. eyeblinking, nose twitching, facial grimacing, head shaking, shoulder shrugging

usually begins in childhood between ages of 2 – 15
worldwide, all races; males more than females
may affect 1 in 2000, worldwide; US ~100,000 affected
may be due to chemical abnormality in basal ganglia
one type of tourette's in inherited

Alzheimers Disease

affect 11% in us over 65; 47% by 85
~half of all nursing home admissions
leading cause of death among elderly
AD may begin before 50 with very mild, undiagnosed symptoms
one of 1st symptoms is memory loss, esp of recent events
progresses with reduced attention span, disorientation, moody, confused, paranoid, combative or hallucinatory
may lose ability to read, write, talk, walk, and eat
death usually from pneumonia or other complications of confinement and immobility

Parkinsons Disease

progressive loss of motor function
begins in 50's or 60's
can be hereditary
due to degeneration of dopamine releasing neurons in substantia nigra (inhibitory neurons)
leads to hyperactivity of basal nuclei and involuntary muscle contractions
results in shaking hands, facial muscles become rigid, range of motion decreases
develops smaller steps, slow shuffling gait with forward bent posture and a tendency to fall forward
speech becomes slurred, handwriting illegible